Averaging top quark results in Run 2

thinkshop^2
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Run 1 CDF/D0 top mass average

Averaging top cross sections

What would make Run 2 top averaging easier?

Run 1 CDF/D0 top mass average

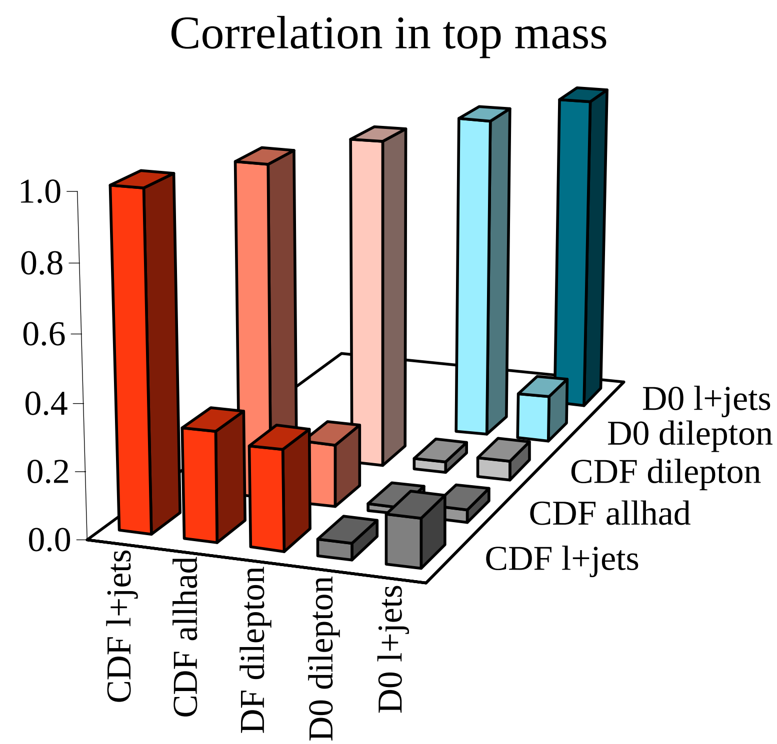
$$\rho_i^{ab} = \frac{\langle \delta_i^a \delta_i^b \rangle}{\sqrt{\langle (\delta_i^a)^2 \rangle \langle (\delta_i^b)^2 \rangle}}$$

$$\rho^{ab} = \frac{\sum_{i=1}^{N} \rho_i^{ab} y_i^a y_i^b}{\sigma^a \sigma^b}$$

$$\mathcal{S}^{ab} = \rho^{ab} \sigma^a \sigma^b$$

$$\langle Q \rangle = \frac{\sum_{a,b=1}^{R} Q^a (\mathcal{S}^{-1})^{ab}}{\sum_{a,b=1}^{R} (\mathcal{S}^{-1})^{ab}}$$

$$\sigma_{\langle Q \rangle} = \frac{1}{\sqrt{\sum_{a,b=1}^{R} (\mathcal{S}^{-1})^{ab}}}$$

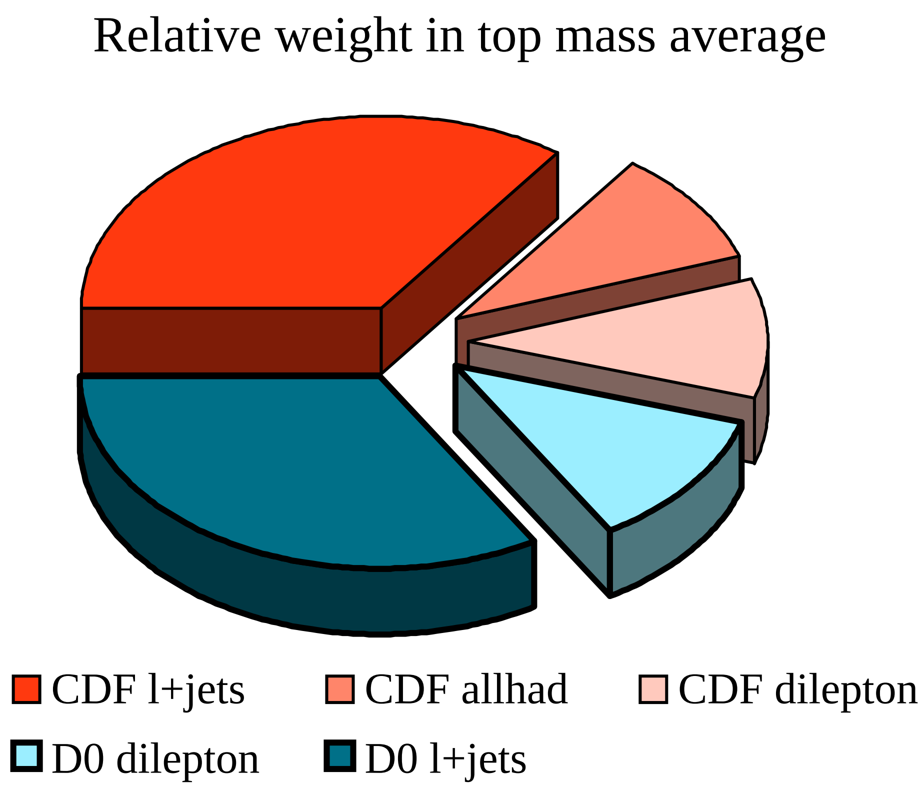


The CDF/D0 Top Averaging Group (Demortier, Hughes, Hall, Klima, Roser, MS) used the above standard formalism to calculate a world average directly measured top mass (FNAL-TM-2084).

We combined R=5 inputs Q^a ($1 \le a,b \le R$) having N=7 error sources ($1 \le i \le N$). In the equations, δ_i is an excursion; y_i is a systematic error; ρ's are correlations; S is the covariance matrix; and the results are $<Q>$ and $\sigma_{<Q>}$.

The Lego plot shows the total correlation ρ^{ab} between pairs of input measurements (a,b). The largest (33%) is between CDF l+jets and CDF allhad; the two major inputs (both l+jets) are 15% correlated.

Run 1 CDF/D0 top mass average (cont'd)



The pie chart shows the relative weights of the five input measurements in the world average. The CDF (35%) and D0 (34%) *l*+jets inputs exert the largest weight.

The same methods were used by each experiment to form its own internal average.

A 3% measurement was achieved:

$$\boldsymbol{m_t = 174.3 \pm 3.2 \pm 4.0 \ \ (174.3 \pm 5.1)}\ \textbf{GeV (combined)}$$

$$m_t = 176.0 \pm 4.0 \pm 5.1 \ \ (176.0 \pm 6.5)\ \text{GeV (CDF only)}$$

$$m_t = 172.1 \pm 5.2 \pm 4.9 \ \ (172.1 \pm 7.1)\ \text{GeV (D0 only)}$$

Averaging top cross sections

D0 merged 9 orthogonal channels with >1 final-state lepton into a single counting experiment. The channels had similar *S/B* .

The combined acceptance error included correlations among 21 sources of systematic error. The formalism was essentially the same as that used for the CDF/D0 top mass average.

For the all jets channel, D0's top cross section instead resulted from a fit to a neural network distribution. It was combined with the earlier result for 9 leptonic channels taking into account 7 sources of correlated systematic error.

Overall, at $m_t = 172$ GeV, D0 obtained

$$\sigma_{tt} = 5.9 \pm 1.2 \pm 1.1 \quad (5.9 \pm 1.7) \text{ pb}$$

CDF uses a likelihood method to combine the cross sections determined from its SVX, DIL, SLT, and HAD channels (these are combinations of distinct subchannels). This allows results from channels with very different *S/B* to be combined without loss of precision.

Again many systematic error correlations are included, using a similar formalism.

At $m_t = 175$ GeV, CDF obtains

$$\sigma_{tt} = 6.5\,^{+1.7}_{-1.4} \text{ pb} \quad \text{(preliminary)}$$

As yet there is no CDF/D0 top cross section average.

What would make Run 2 top averaging easier?

- One experiment could stumble.

- Both experiments could decide in advance to group their sources of systematic error into similar categories. Error sources that belong to the same category should have:

  little correlation with error sources that belong to other categories;

  a similar degree of correlation with members of the same category for a different measurement;

  a related physical origin (*e.g.* so that it might be informative to study the effect of varying the error scale for a particular category).

For the Run 1 top mass average, we used categories

jet energy scale

model for signal

Monte Carlo generator

multiple interactions / U noise

model for background

method for mass fitting

As the Run 2 measurements become more precise, these categories will need to be defined more rationally and precisely, and their number may need to increase.

What would make Run 2 top averaging easier? (cont'd)

- In an effort to be "conservative", the degree to which systematic errors are correlated between different measurements may deliberately be overestimated. This can have unforeseen consequences and should be avoided.

As an example, consider a precise measurement a and a coarse measurement b of a quantity whose true value is c. Define $\delta a = a - c$, $\delta b = b - c$.

Consider the limiting case in which the two measurements are "conservatively" taken to have uncertainties that are maximally correlated. Then $\delta a = f\,\delta b$, where $f < 1$ because a is the better measurement.

Solving these 3 equations for the 3 unknowns c, δa, and δb, one obtains

$$c = a - f\,(b-a)/(1-f)\ .$$

In this limiting case, the result has two bizarre properties:

- c is measured to arbitrarily high precision.
- taking into account the coarser measurement b moves the best estimate for c outside the interval (a,b) .

So much for conservatism. Instead we should try to make the best estimates we can.